

UNIVERSITY OF TECHNOLOGY SYDNEY  
Faculty of Engineering and Information Technology

# **Cooperative Vehicular Networks for Intelligent Transportation Systems**

by

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## Certificate of Authorship/Originality

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## ABSTRACT

### **Cooperative Vehicular Networks for Intelligent Transportation Systems**

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Transportation systems are fundamental for the human society as they allow people and goods to move from one location to another. With an increasing volume of population and vehicles, current transportation systems are now facing a number of disruptive challenges such as congestion, crashes, air pollution and noise throughout the world. However, traditional solutions like expanding the present transportation systems by increasing the number of roads are recognized to be expensive, disruptive and involve protracted effort. Instead, intelligent transportation systems (ITS), with the goal of building a safer, more efficient and environmentally sustainable transportation system by incorporating state-of-the-art sensing, computing and communication technologies, is expected to be a better solution.

ITS are complex systems and they function in a broad range of areas through smartly sensing, analysing and disseminating different kinds of traffic information. Vehicular networks, which incorporate advanced communication technology with intelligent vehicles equipped with on-board units (OBUs) and intelligent roadside infrastructure, realise the function of large scale traffic information dissemination for ITS through vehicle to vehicle (V2V), vehicle to infrastructure (V2I) and infrastructure to infrastructure (I2I) communications. Therefore, as one of the most enabling tools to support ITS, vehicular networks play a crucial role in improving road safety, relieving traffic congestion, enhancing driving experience and reducing pollution.

Considering the critical impact information exchange poses on the transportation systems, vehicular network applications require particularly fast, reliable and secure

message dissemination in the network. However, depending only on V2V or V2I communications may fail to meet these requirements. On one hand, the frequently changing topology of vehicular networks caused by the highly dynamic nature of vehicles and the lossy vehicular wireless channels resulting from fading, path loss and the fast movement of vehicles, would result in unreliable and intermittent V2V communications. On the other hand, V2I communications may have limited availability, especially in rural areas and in the initial deployment phase of vehicular networks due to the high cost of implementation and maintenance of infrastructure. These make research on employing cooperative communications within vehicular networks both interesting and important.

In this thesis, we focus on the design of cooperative vehicular networks for ITS to satisfy the requirement of disseminating data quickly, reliably and securely, in the conditions of sparse roadside infrastructure, high mobility, and intermittent connectivity. Firstly, we propose a cooperative communication strategy that explores the combined use of V2I communications, V2V communications, mobility of vehicles, and cooperation among vehicles and infrastructure, to facilitate data dissemination in vehicular networks. The network performance, measured by the achievable throughput when there exists only one vehicle with a download request in the network, and the achievable capacity when there exist multiple vehicles with download requests in the network respectively, are analysed. The results show that the proposed cooperative communication strategy significantly boosts the throughput (or capacity) of vehicular networks. Secondly, to protect secure message dissemination, we investigate topological approaches to keep the message dissemination in vehicular networks robust against insider attackers who may tamper with the message content. As a novel approach, we take the network topology into consideration when designing algorithms to check the integrity and consistency of messages. Overall, our work provides guidance on the optimum design of cooperative vehicular networks for ITS to achieve fast, reliable and secure message dissemination.

Dissertation directed by Professor Guoqiang Mao

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## List of Publications

The following is a list of publications in refereed journals and conference proceedings produced during my Ph.D. candidature. In some cases, the journal papers contain material overlapping with the conference publications.

### Journal Papers

- J-1. **J. Chen**, G. Mao, C. Li, D. Zhang, “A Topological Approach to Secure Message Dissemination in Vehicular Networks,” Accepted by *IEEE Transactions on Intelligent Transportation Systems*, Dec. 2018.
- J-2. **J. Chen**, G. Mao, C. Li, W. Liang, D. Zhang, “Capacity of Cooperative Vehicular Networks with Infrastructure Support: Multi-user Case,” *IEEE Transactions on Vehicular Technologies*, vol. 67, no. 2, pp. 1546 - 1560, Feb. 2018.
- J-3. **J. Chen**, G. Mao, C. Li, A. Zafar, A. Y. Zomaya, “Throughput of infrastructure-based cooperative vehicular networks,” *IEEE Transactions on Intelligent Transportation Systems*, vol. 18, no. 11, pp. 2964-2979, Nov. 2017.
- J-4. **J. Chen**, G. Mao, “On the Security of Warning Message Dissemination in Vehicular Ad Hoc Networks,” *Journal of Communications and Information Networks*, vol. 2, no. 2, pp 4658, Jun. 2017

### Conference Papers

- C-1. **J. Chen**, G. Mao, “Secure Message Dissemination in Vehicular Networks: A Topological Approach,” *IEEE Global Communications Conference (GlobeCom)*, 2018
- C-2. **J. Chen**, G. Mao, C. Li, “Capacity of Infrastructure-based Cooperative Vehicular Networks,” *IEEE Global Communications Conference (GlobeCom)*, 2017

- C-3. **J. Chen**, A. Zafar, G. Mao, C. Li, “On the achievable throughput of cooperative vehicular networks,” *IEEE International Conference on Communications (ICC)*, 2016

# Contents

Certificate	ii
Abstract	iii
Acknowledgments	v
List of Publications	vi
List of Figures	xii
<b>1 Introduction</b>	<b>1</b>
1.1 Research Background . . . . .	1
1.1.1 Intelligent Transportation Systems . . . . .	1
1.1.2 Vehicular Networks . . . . .	3
1.2 Research Motivation . . . . .	6
1.2.1 Cooperative Communications . . . . .	6
1.2.2 Vehicular Network Capacity . . . . .	7
1.2.3 Vehicular Network Security . . . . .	8
1.3 Research Objectives and Contributions . . . . .	9
1.4 Thesis Organization . . . . .	13
<b>2 Literature Review</b>	<b>14</b>
2.1 Cooperative Vehicular Networks . . . . .	14
2.1.1 Cooperation among Vehicles . . . . .	14
2.1.2 Cooperation among Infrastructure Points . . . . .	15



2.1.3	Cooperation among Both Vehicles and Infrastructure Points . . . . .	16
2.2	Capacity of Vehicular Networks . . . . .	17
2.3	Security of Vehicular Networks . . . . .	18
<b>3</b>	<b>Throughput of Cooperative Vehicular Networks with Infrastructure Support: Single-user Case</b>	<b>21</b>
3.1	System Model and Problem Formation . . . . .	22
3.1.1	Network Model . . . . .	22
3.1.2	Wireless Communication Model . . . . .	23
3.1.3	Cooperative Communication Strategy . . . . .	26
3.1.4	Problem Formation . . . . .	28
3.2	Analysis of V2V Communication Process and Achievable Throughput	32
3.2.1	Infrastructure-Limited Regime . . . . .	33
3.2.2	V2V-Limited Regime . . . . .	40
3.2.3	Transitional Regime . . . . .	44
3.3	Simulation and Discussion . . . . .	49
3.4	Summary . . . . .	59
<b>4</b>	<b>Capacity of Cooperative Vehicular Networks with Infrastructure Support: Multi-user Case</b>	<b>60</b>
4.1	System Model and Problem Formation . . . . .	61
4.1.1	Network Model . . . . .	61
4.1.2	Wireless Communication Model . . . . .	61
4.1.3	Cooperative Communication Strategy . . . . .	62
4.1.4	Problem Formation . . . . .	63
4.2	Analysis of the Capacity . . . . .	64

4.2.1	Capacity Achieved from V2I Communications . . . . .	65
4.2.2	Capacity Achieved from V2V Communications . . . . .	66
4.2.3	Achievable Capacity . . . . .	74
4.3	Simulation and Discussion . . . . .	76
4.4	Summary . . . . .	85
<b>5</b>	<b>A Topological Approach to Secure Message Dissemination in Vehicular Networks</b>	<b>86</b>
5.1	System Model and Problem Formation . . . . .	87
5.1.1	Network and Message Dissemination Model . . . . .	87
5.1.2	Attack Model . . . . .	88
5.1.3	Problem Formation . . . . .	90
5.2	Optimum Decision Algorithm . . . . .	92
5.2.1	Optimum Decision Algorithm . . . . .	92
5.2.2	Algorithm Implementation . . . . .	95
5.2.3	A Discussion of the Optimum Algorithm . . . . .	101
5.3	Heuristic Decision Algorithm . . . . .	103
5.4	Simulation and Discussion . . . . .	110
5.4.1	Comparison of the Two Proposed Algorithms . . . . .	112
5.4.2	Impact of Topology Information . . . . .	114
5.4.3	Impact of the Percentage of Malicious Vehicles . . . . .	115
5.4.4	Impact of the Waiting Time Period . . . . .	116
5.5	Summary . . . . .	117
<b>6</b>	<b>Conclusion</b>	<b>119</b>

<b>Appendices</b>	<b>122</b>
<b>A Proof of Theorem 4.2 in Chapter 4.2.2</b>	<b>123</b>
<b>B Proof of Theorem 4.3 in Chapter 4.2.2</b>	<b>125</b>
<b>C Proof of Theorem 4.5 in Chapter 4.2.3</b>	<b>131</b>
<b>Bibliography</b>	<b>135</b>

# List of Figures

1.1	An illustration of vehicular networks. . . . .	3
3.1	An illustration of the system model for a bi-directional highway with infrastructure regularly deployed with equal distance $d$ : single-user case. . . . .	23
3.2	An illustration of helpers encountered by the VoI during one V2V communication cycle and their interval distance. . . . .	30
3.3	An illustration of clusters formed by the helpers. . . . .	38
3.4	A comparison between the result of $E[D_{V1}]$ with and without the approximation. . . . .	39
3.5	A comparison between our analytical results and the simulation results under each regime, with different helpers' density $\rho_2$ . . . . .	50
3.6	A comparison between the throughput achieved from vehicular networks with and without cooperative communication. . . . .	53
3.7	A comparison between the throughput achieved from our proposed strategy and that from the strategy proposed in [49]. . . . .	54
3.8	A comparison between throughput achieved from the constant speed model and the time-varying speed model which follows Gaussian distribution. . . . .	55
3.9	A comparison between throughput achieved from the unit disk model and the log-normal connection model. . . . .	56

3.10	A comparison between throughput achieved when allowing one-hop communication and multi-hop communications. . . . .	57
3.11	A comparison between throughput achieved from constant channel model and time-varying channel model which considering Rayleigh fading and path loss. . . . .	58
4.1	An illustration of the system model for a bi-directional highway with infrastructure regularly deployed with equal distance $d$ : multi-user case. . . . .	62
4.2	An illustration of one cycle, which includes V2I Area and V2V Area.	65
4.3	An illustration of the distribution of distances between two consecutive simultaneous transmitters. . . . .	70
4.4	A comparison of the expected number of simultaneously active helper-VoI pairs in one V2V Area with respect to the proportion of VoIs $p$ between simulation and analysis, for different sensing ranges $R_c$ . . . . .	77
4.5	A comparison of the capacities achieved from one cycle by all VoIs, by all VoIs in the eastbound direction, and by all VoIs in the westbound direction as a function of the proportion of VoIs $p$ . . . . .	79
4.6	Relationship between capacity, distance between adjacent infrastructure points and vehicular density. . . . .	80
4.7	A comparison between the capacity achieved from one cycle, with and without cooperative communications. . . . .	81
4.8	A comparison between the capacity achieved from one cycle assuming our proposed strategy and that assuming the strategy proposed in [49]. . . . .	83
4.9	A comparison between capacity achieved from one cycle when allowing one-hop communication and multi-hop communications. . . . .	83

4.10	A comparison between capacity achieved from the constant channel model and the time-varying channel model which considers Rayleigh fading and path loss. . . . .	85
5.1	An illustration of a vehicular network when there exists a malicious vehicle $V_2$ who would tamper with the content of message. . . . .	89
5.2	An illustration of a vehicular network that contains 7 independent paths from the source vehicle to the destination vehicle, containing 1, 8, 15, 6, 6, 6, and 6 vehicles respectively. . . . .	102
5.3	An illustration to show that the percentage of malicious vehicles is indispensable in implementing the optimum decision algorithm to achieve an accurate decision result. . . . .	103
5.4	An illustration to show the malicious cut sets and minimum malicious cut sets of a network. . . . .	106
5.5	An illustration of two networks that have the same topology matrix. . . . .	109
5.6	An illustration of the target road segment. . . . .	111
5.7	A comparison of the probabilities of a correct decision achieved by the optimum decision algorithm proposed in Section 5.2, and by the heuristic decision algorithm proposed in Section 5.3. . . . .	113
5.8	A comparison of the probability of a correct decision achieved assuming our proposed algorithms and that achieved assuming other existing weighted voting algorithms. . . . .	115
5.9	An illustration of the relationship between the probability of a correct decision and the waiting time period the destination vehicle waits before it starts to make a final decision by adopting the proposed two algorithms respectively. . . . .	116

A.1	An illustration of the distribution of simultaneous transmitters, where the triangular points represent the helpers that are chosen as simultaneous transmitters and the dots represent the helpers that are not chosen as transmitters. . . . .	124
B.1	An illustration of the distribution of distances between two consecutive simultaneous transmitters. . . . .	125
B.2	An illustration of the case that the helper $V_{k,1}$ is chosen as the ( $k + 1$ )-th transmitter. . . . .	127
C.1	An illustration of the coordinate system, the location of the randomly chosen transmitter, and the left-most VoI from each direction that are located at the right of origin. . . . .	132